Saskatchewan Technology Enhancement Program

Cover Type Mapping in the Commercial Forest Region of Saskatchewan for Moose Habitat

by

J. Polson
Saskatchewan Research Council

SRC Technical Report No. 207
September, 1987

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Energy, Mines and Resources Canada

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SRC Technical Report No. 207

SRC Publication No. E-905-21-B-87
September, 1987

PUBLISHED BY:

Saskatchewan Research Council
15 Innovation Blvd.
Saskatoon, Sask.
Canada S7N 2X8

Coordinated by:

J. Whiting

This report was produced by SRC Graphic Services - Desktop Publishing System.

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1. INTRODUCTION

In January 1985 a Memorandum of Understanding for cooperation in remote sensing was signed between the Canada Centre for Remote Sensing (CCRS), Energy Mines and Resources, and the Saskatchewan Research Council (SRC). The agreement, the Saskatchewan Technology Enhancement Program (STEP), was a cooperative undertaking whereby CCRS loaned a ARIES[1] II digital image analysis system, and provided the full time services of a remote sensing specialist to assist in using the system and to advise cooperating investigators. The STEP was to be completed in June 1987. A portfolio of joint projects was undertaken by a number of Saskatchewan government agencies at no cost for computer time or training of personnel. The image analysis system was installed at the SRC laboratories in Saskatoon by January 1985. Work on the pilot projects commenced at the same time.

Although extensive development in logging, mining and road construction has occurred in the northern Saskatchewan in recent years no useful land cover maps were available. Forest Inventory Maps (FIM) at scales of 1:25,000 and 1:12,000 were available for the commercial forest area. However, these were very detailed and not suitable as general cover maps for use in resource planning. In a meeting with the representatives of the Wildlife Branch of SPRR the recommendation was that the Wapawekka area (73I), in the commercial forest zone, be chosen as a test area to test the feasibility of digital Landsat MSS data for creating a vegetation map useful to the wildlife biologist.

1) Mention or failure to mention commercial trade names does not imply endorsement or criticism by the Government of Canada or the Government of Saskatchewan.

2. OBJECTIVES

The objectives of the study were to:

1) assess the feasibility of using Landsat Multi Spectral Scanner (MSS) data to map major vegetation types in the Wapawekka area;
2) create a thematic map at scales of 1:250,000 and 1:125,000 and
3) compare the thematic map data to existing forest cover maps.

3. STUDY AREA

3.1 Location

The region covered by the Wapawekka map sheet is located in east central Saskatchewan between 54° and 55° north latitude and 104° and 106° west longitude (Figure 1). It occupies about 1.5 million ha (14,244 km^{2}) (Head *et al.* 1981).

3.2 Physiography

North of Wapawekka Lake lies the Churchill River Plains Region of the Churchill Province of the Canadian Shield. The terrain consists of an undulating to moderately rolling ice-scoured bedrock plain. Granitic, metamorphic and extrusive volcanic bedrock associated with coarse textured glacial till is found in the uplands while depressions are generally occupied by organic or lacustrine deposits (Head *et al.* 1981).

The remainder of the study area lies within the Saskatchewan Plains Region of the Interior Plains of North America. This consists of two uplands: the Wapawekka Hills Uplands and the undulating to hilly morainic plains with strongly dissected north and east facing escarpments. This area is made up of coarse and moderately fine textured glacial tills with some fluvial and organic deposits. The Waskesiu Hills Uplands is gently to strongly rolling morainic topography consisting of medium textured glacial till and local sand and gravel deposits.

Almost one half of the study area is covered with gray luvisol (grey-wooded) soils which occur under forest vegetation on the medium to moderately fine textured glacial till and lacustrine deposits. Eutric brunisols are found under forests associated with coarse textured gravelly or sandy soils. Poorly drained organic or Gleysolic soils occur in depressional and low lying areas. The latter two soil classes cover 16 and 22 of the map area respectively (Head *et al.* 1981).

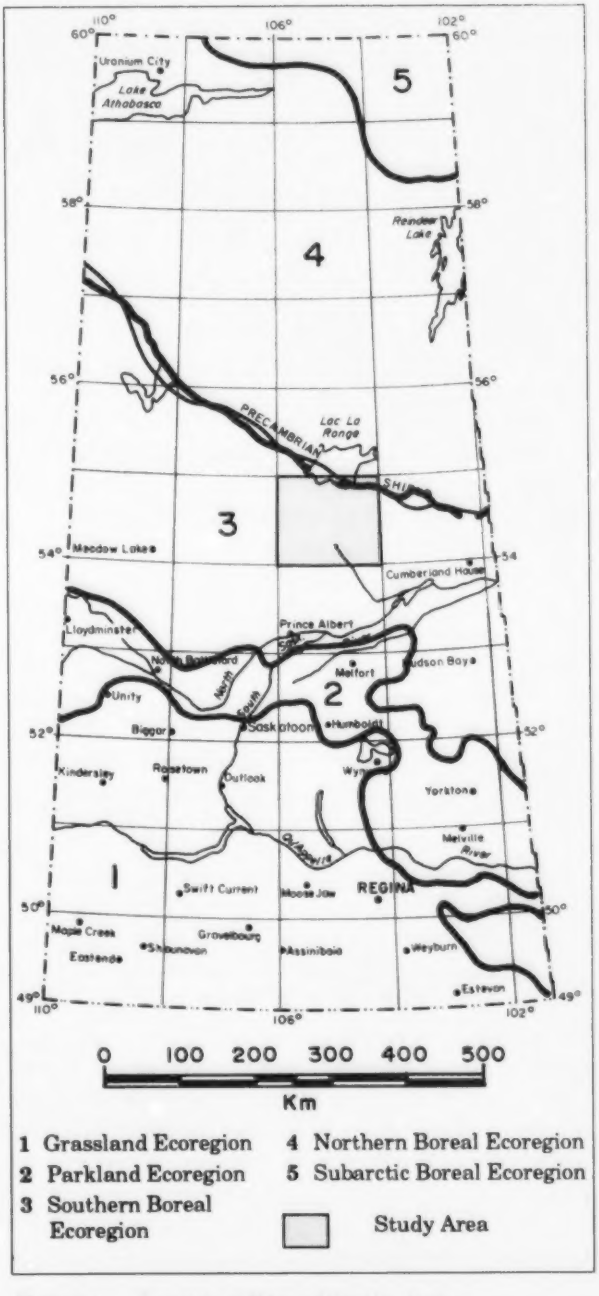

Figure 1. Location Map of Study Area.

3.3 Vegetation

The study area is located within the Mixedwood section of the southern boreal ecoregion as described by Harris *et al.* (1983). Within the region, trembling aspen (*Populus tremuloides*) dominates hardwood forests while balsam poplar (*Populus balsamifera*) can be found on moister upland sites. White birch (*Betula paperifera*) is also present and can be locally abundant. Softwood species include black and white spruce (*Picea mariana* and *P. glauca*) and jack pine (*Pinus banksiana*) in uplands with black spruce and tamarack (*Larix laricina*) growing in poorly drained areas. Balsam fir (*Abies balsamea*) occurs in limited amounts.

3.4 Natural History

The Mixedwood section of the boreal forest represents some of the richest and most diverse wildlife habitat in the forested portion of Saskatchewan. It is the site of converging eastern and western avi-fauna resulting in great species diversity. Small mammals and their accompanying avian and mammalian predators are common and species diversity is high. Ungulates are well represented and include the white-tailed deer (*Odocoileus virginianus*), mule deer (*Odocoileus hemionus*), elk (*Cervus canadensis*), woodland caribou (*Rangifer tarandus*) and moose (*Alces alces*). Moose populations are highest in this regionof the boreal forest and reach their highest densities in the deciduous and deciduous dominant mixedwoods.

4. METHODS

4.1 Data Acquisition

Few satellite images of optimal data were available for the study. The most suitable date was determined by purchasing and reviewing a number of colour prints and transparencies of the commercial forest zone during different periods of the growing season, that is from early spring to late fall (1976-1984).

A single summer 1984 colour print at a scale of 1:250,000 was obtained (Table 1). A computer compatible tape (CCT) was also purchased of data from June 10, 1984. An October 8 image from 1984 was obtained, in CCT format, in addition to the June image. The quality of the fall scene was, however, poor with approximately one half of the scene covered by light haze.

4.2 Data Sources

Air photo coverage for the area was available at scales of 1:60,000 dating from 1960 and 1:12,500 (1983-1984). Forest inventory maps (FIM) were also available for the entire area at scales of 1:12,500 and 1:25,000.

A field trip was made to become familiar with the area and to locate suitable training areas for the digital classification. Many of the original ground control points proved unsuitable and were impossible to accurately locate on the Landsat imagery during the supervised classification process. However, a few ground control points represented pure stands of single species. These data were found to be the most suitable for use in the supervised classification.

An aerial reconnaissance was, conducted to locate, map and photograph additional ground control sites. Additional training area data were supplied by the Forestry Branch of SPRR in Prince Albert from 1983-1984 air photos of the region.

The forest fire history of the region was obtained from the Fire Control Branch of SPRR and from sequential Landsat colour transparencies dating back to 1976.

4.3 Landsat Classification

Digital image analyse were performed from February 1985 to March 1986. The methodology used to classify the area is shown in Figure 2.

Table 1.
List of Image Products Obtained for the Wapawekka Study Area.

Track & Row	Date of Image	Landsat	Product	Scale
40/22	August 3, 1976	2	Colour Transparency	1:1,000,000
"	September 3, 1977	2	" "	"
"	October 2, 1980	2	" "	"
"	October 2, 1980	2	Colour print	1:250,000
37/22	June 10, 1984	4	Colour transparency	1:1,000,000
"	June 10, 1984	4	Colour print	1:250,000
"	June 10, 1984	4	MSS computer tape	---
"	October 8, 1984	5	Colour transparency	1:1,000,000
"	October 8, 1984	5	Colour print	1:250,000
"	October 8, 1984	5	MSS computer tape	---

The image from June 10 was geometrically corrected prior to performing any classification operations in order to more easily locate training areas and assess the accuracy of the classification. A good distribution of ground control points over the entire image provided corrections to the image of less than 1/2 pixel. Pixels were resampled to 50 x 50 m. Ground control points from the map included small islands, narrow peninsulas and distinctive rivers. Roads were not used as they were not accurately mapped in the north.

Linear enhancements were developed for all subareas prior to classification to improve the visual differentiation of the cover types. Limited experimentation was conducted with band ratio enhancements to produce imagery suitable for the differentiation of individual softwood species.

The parallel piped classifier was used extensively in the early stages of the classification process. The reflectance uniqueness of various cover types was explored and a decision made to include them as a separate class within the study region. Small subareas representing the variety of habitats were classified using bands 7 and 5. Pixel by pixel and training area options were used in an effort to identify reflectance overlaps which occurred between the habitat types. Class overlaps were identified by viewing the resulting scattergrams. As a result of preliminary classifications the original classes. A feedback loop was used to decide whether supervised and unsupervised options were used and which signature classes would have to be manually created.

Landsat imagery was visually interpreted for dating forest fires and updating roads. (The latter is important to wildlife managers for controlling illegal and legal hunting on game populations). Sequential imagery at a scale of 1:1,000,000 dating back to 1976 were used to locate and map forest fires.

A preliminary road map was constructed by overlaying a copy of the 1963 1:250,000 topographic map, reproduced on mylar, on the June 10, 1984 print of the Landsat image. To reduce the effect of image distortion roads were traced over a small area and the mylar shifted slightly to realign it with the image underneath.

Six subareas were chosen in various locations on the image to represent reflectance differences. For each subarea histograms of the four MSS bands were displayed and searched for local maxima peaks. Up to 32 local maxima were stored in order of significance. Maxima were ranked by mean and standard deviation in each reflectance band. Themaxima were then merged into clusters based on their association similarities.

A standard maximum likelihood classifier was then performed using the signature files. After completing the initial classification classes were compared with ground cover data using air photos and FIM's. Classes which appeared to represent the same cover type were combined and the data rerun through the maximum likelihood classifier. Signature files associated with classes that accurately portrayed the cover types found on the image were then used in the final classification of the entire study area.

Supervised classification was performed on several subareas previously used in the unsupervised operation. Several new subareas were also chosen to portray the wide range of lake water reflectances and several forest types not properly classified using the unsupervised program. Various sources of ground data were used to locate and outline training areas which represented pure stands of jack pine, black spruce, and trembling aspen. These data included training areas selected from interpretation of infrared and black and white air photos (1:12,000), ground data and FIM. FIM's were only used in selecting training areas for the open marsh and treed bog cover types. Signature files obtained from the supervised clustering of reflectances were run through the maximum likelihood classifier. Results of the classification were checked with air photo coverage and FIM's. Classes which appeared to accurately represent a particular cover type were retained for classification of the larger image.

Suitable signature files obtained from supervised and unsupervised classification of the various subareas were combined using the maximum likelihood classifier to produce the final classification of the entire Wapawekka area map.

4.4 Accuracy Assessment

An accuracy assessment of the vegetation-based thematic map was conducted in three

phases. Preliminary assessment of the map consisted of subjective evaluation based on previous knowledge of the area. This phase identified gross deficiencies in maps. It also compared relatively large homogeneous blocks of cover on the thematic map with the corresponding areas on the ground.

The remaining methods of investigation involved of comparing segments of the thematic map with the FIM. A general assessment of the accuracy of the thematic map compared with the forestry data was conducted by first colour coding by hand four segments of the FIM's and then comparing these classes to those of the thematic map.

A more detailed comparison of individual pixels was also done. Ten representative segments of the thematic map were printed at the same scale as the FIM's, 1:25,000, with UTM grid overlays for each map. Four pixels around the intersection point of each UTM grid line were compared to the same area on the FIM. Errors of commission and omission were noted by recording the cover types of the point by comparing the total sample points for each cover type in order to arrive at accuracy levels.

5. RESULTS AND DISCUSSION

Classification of the Wapawekka map sheet resulted in 12 classes categorizing both the natural cover types and those influenced by man (Table 2).

A colour coded thematic map was produced at scales of 1:125,000 and 1:250,000. Area calculations were generated with percent of total map and area given for each cover class (Table 3).

Table 2.
List of Classes Derived from Digitial Classification of the Wapawekka Study Area.

1. Water bodies	7. Willow - shrub
2. Coniferous forest	8. Open jack pine forest
3. Deciduous forest	9. 1977-1983 burns
4. Deciduous dominant mixedwood forest	10. 1984 burns
5. Treed bog	11. Regenerating cutovers
6. Open bog - marsh	12. Recent or sparsely vegetated cutovers

5.1 Accuracy Assessment

A review of the thematic map indicated agreement with actual cover types at the stand level with disagreement occurring at the pixel level. Some areas were classified as deciduous forest with a few scattered pixels indicating mixedwoods or softwoods. Some areas on the FIM were classified as deciduous. However, aerial reconnaissance revealed that there was a softwood component in these stands as well. The most significant deficiencies in the thematic map were open stands of jack pine confused with open bog habitats; upland coniferous forest confused with dense treed bog; confusion between open and treed bog and confusion between pure stands of conifer, deciduous and mixedwoods.

Errors of commission and omission were obtained during the detailed assessment (Table 4). The detailed assessment did however place percentages on the errors. A comparison between

Table 3.
Percent Area and Number of Hectares of 12 Cover Classes Calculated of the Wapawekka Study Area.

Class	Number of Hectares	Percent Total Area
1. Water bodies	137,186	9.4
2. Coniferous forest	594,925	40.8
3. Deciduous forest	47,954	3.3
4. Deciduous dominant mixedwood forest	110,726	7.6
5. Treed bog	279,443	19.2
6. Open bog - marsh	36,150	2.5
7. Willow - shrub	26,602	1.8
8. Open jack pine forest	30,081	2.1
9. 1977-1983 burns	147,434	10.1
10. 1984 burns	8,121	0.6
11. Regenerating cutovers	19,670	1.3
12. Recent or sparsely vegetated cutovers	9,247	0.6
Unclassified	9,693	0.7
Multiple classified pixels	1,913	0.1
Total of the 12 Cover Classes	1,447,539	100.0

Table 4.
A Comparison of Sample Units from the Landsat Thematic Maps to the Forest Inventory Maps.

Landsat Theme	Forest Inventory Categories % Agreement						
	Water	Soft-wood	Hard-wood	Mixed-wood	Treed Bog	Open Muskeg	Brush-land
Lakes	95.0	1.4	0.0	0.7	0.7	0.7	1.4
Coniferous Forest	0.1	64.5	1.6	8.6	20.5	2.5	2.1
Deciduous Forest	0.0	10.8	65.7	16.6	2.9	0.0	3.9
Deciduous Mixed Forest	0.0	23.4	21.0	27.5	10.2	1.2	4.2
Treed Bog	0.4	17.5	2.5	3.2	51.1	23.2	2.1
Open Bog Marsh	0.0	0.0	0.0	0.0	52.5	40.0	7.5
Willow/Shrub	0.0	2.2	6.5	8.7	45.7	34.8	2.2
Open Jack Pine	0.0	29.5*	0.0	0.0	34.1	34.1	2.3

*not distinguished from the general softwood category.

the thematic map and the forest inventory map segments of 1457 sample points from nine subareas resulted in an overall agreement of 58%. This ranged from a high of 95% with the water bodies to a low of 28% in the mixedwoods category.

Some confusion existed between water bodies and softwood forest, mixedwoods and treed and open bog. Edge pixels and confusion with unmapped standing water bodies or wet areas within bogs appeared to accounted for the majority of the disagreement.

Twenty-one percent of the disagreement in the conifer-dominant forest class occurred when areas identified as treed bog on the FIM were classified as coniferous or softwood forest on the thematic map. Nine percent of the softwood forest were considered hardwood-softwood mixedwood forest by FIM. Open bog and FIM-designated brushland class made up the remaining 5% of the disagreement. Preliminary examination of the thematic map had identified the confusion between the upland coniferous forest and dense treed bog which was confirmed by the satellite generated thematic map.

Scattered occurrences of softwoods in areas designated as mixedwoods (according to FIM) was also understandable. The confusion between the open bog may represent legitimate reflectance overlap between the two classes or occurrences of some undetected or unrecorded islands of softwoods within the FIM classification. The FIM was drawn on a slightly coarser scale, equivalent to 4 pixels. Post classification filtering was not performed on the final thematic map, and therefore areas as small as one pixel occur.

Of the 35% disagreement with the FIM one half or 17% occurred when pixels were assigned to the deciduous dominant mixedwoods class and 11% was classified as softwood dominant forest. The remainder was classified as open bog or brushland.

Much of the disagreement between the deciduous and mixedwoods designations may be accurate. Individual pixels marked as deciduous likely occur within mixedwood stands where clumps of aspen, birch or balsam poplar coexist. Definition of pure stands allow up to 20% inclusion of other species. A similar argument can be made for confusion with FIM softwood classification where pockets of hardwoods can occur within stands. The remaining 6% disagreement between the thematic map and the FIM may or may not be a result of reflectances similarities. However,

deciduous species will occur in the brushland class and there is some evidence to suggest that tamarack may have a similar signature to some deciduous species.

The deciduous-dominant mixedwood forest class represented the lowest level of agreement (27.5%) between the thematic map and the FIM. The majority of the confusion was between pixels classified into either the deciduous or coniferous classes, since these components are present in the mixedwood category. It is not known whether the 10% classified as treed bog is due to reflectance similarities or other unrecorded occurrences of species present in the areas.

Two factors contributed to the disagreement noted in the treed bog class (57.1%). Difficulties were encountered in separating upland and lowland softwood forest where softwood densities were high. This represented 18% of the area classified as coniferous forest in the thematic map. Twenty-three percent of the misclassified treed bog category was allotted to open bog and probably represented pixels at the interface of the two cover types and unrecorded clumps of dense spruce or jack pine. The minor amounts of deciduous and mixedwoods disagreement found in the treed bog classification may represent problems with the classification or unrecorded occurrences of these groups.

Almost all of the misclassified areas in the open bog and marsh cover type were designated as treed bog on the FIM. Much of this was probably due to edge pixels and unrecorded occurrences of softwoods. Errors in choosing training areas which only included open bog and marsh habitat also resulted in the overlap of the open and treed bog classes. Although separated in the analysis, the agreement between the marsh class according to FIM and the open bog-marsh designations on the thematic map were good.

Very poor agreement occurred in the willow-shrub class between the thematic map and the FIM. Some of the disagreement is caused by shrub components in the open and treed bog classes but much of the disagreement stems from difficulties in distinguishing between willows and deciduous tree species. Further work on this problem would either result in the removal of this class or additional experimentation on methodologies to separate these closely related reflectance classes.

The open jack pine forest was combined with the coniferous dominant forest type. Although no direct comparison was made between the thematic map and the FIM for this cover type, subjective evaluation indicated that the classification readily picked up most of the open jack pine stands but also resulted in some confusion with some areas of open bog.

6. METHODOLOGY ASSESSMENT AND MODIFICATION

The final classification consisted of 28 signature files created from six subareas and took 53 hours of computer time to run. The methodology required severe modifications. A more streamlined method is shown in Figure 2 and was used to run the classification of the area a second time. Computer batch time was reduced to 7 hours. Several significant points should be raised regarding the more streamlined method.

a) Signature files developed through the interactive training program were created by updating a series of training files chosen to represent possible reflectance differences which can occur from one portion of the image to another.

b) Maxima developed from reflectance values of the image files used in unsupervised classification were obtained for the entire image to be classified. These maxima were then used to create signature files. Their suitability was determined by using them to classify small subareas.

c) The use of small subareas during unsupervised classification allowed the operator to use the maximum number of maxima classes during the initial run of the classification and then manually allot them to the right class. This method allowed much greater operator input into the classification process then if the computer was allowed to do all the lumping.

It is strongly recommended that the staff at the Prince Albert Satellite Station assist in choosing suitable quality imagery. The ability to detect haze on the microfiche, in particular, requires somepractice and such imagery must be avoided for any digital classification.

When purchasing satellite imagery for a new area it is often useful to obtain imagery for more than a single date. This can be done most

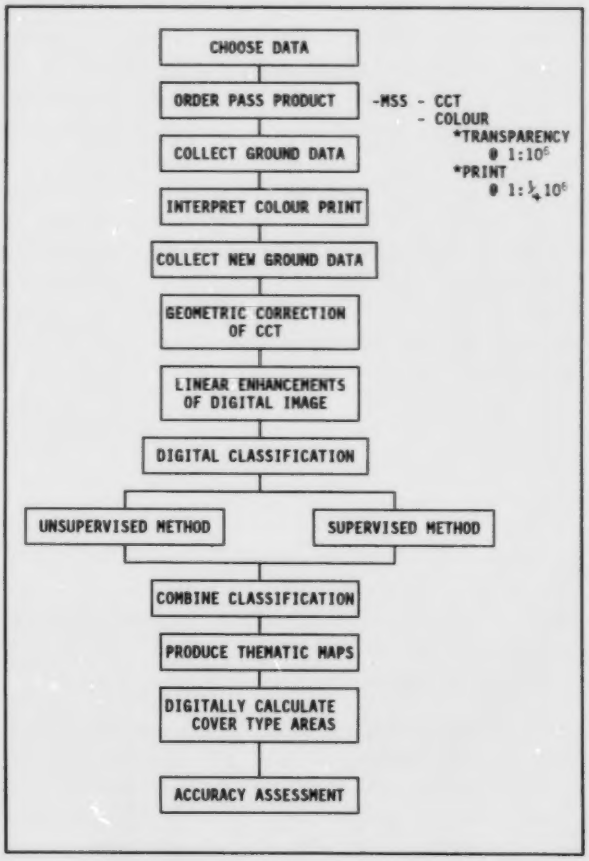

Figure 2. Schematic Diagram of Classification Methodology.

economically by purchasing 1:1,000,000 scale colour transparencies. If you are interested in sequential development of the area including changes in roads, logging area, forest fires etc. these can all be quickly determined through visual interpretation of the transparency.

In the forest region, when single date imagery is to be used in the digital classification, a mid June to early August image is the best compromise for differentiating forest types and delineating roads, burns and cutovers. The

simultaneous classification of two dates, i.e. summer and fall (after leaf fall in deciduous species) improves classification accuracy significantly.

After an initial attempt to classify the image problem classes should be considered on an individual basis using taylor-made enhancements or manual classification to improve their delineation.

Not all cover types can be classified digitally. Visual interpretation of transparencies or paper prints can be used to add roads, locations of logged areas and burns. Discrete areas such as cutovers and burns can be included using the manual theme task to draw in boundaries.

A small subarea in the southwest corner of the study area was used to experiment the use of multi-date image analysis to further separate forest cover classes. The area located in Prince Albert National Park supports extensive areas of deciduous and deciduous dominant mixedwoods forests.

Bands 5 and 7 from both the June 10 and October 8, 1984 MSS images were classified using unsupervised classification and the Maximum Likelihood Classifier. Preliminary results indicated that:

a) Pure hardwood stands can be distinguished from hardwood dominant mixedwood forest.

b) Several classes of hardwood dominant mixedwoods can be distinguished according to the type and amount of softwood present.

c) Trembling aspen and young jack pine which have similar summer reflectances can be readily separated in logged areas by using both a summer and fall image in the digital analysis. Providing the fall image obtained is for the period after leaf fall.

7. CONCLUSIONS

The classification at map scales of 1:125,000 and 1:250,000 curently being assessed.

The use of digital Landsat MSS data appears to provide a means of rapidly mapping major cover types in northern Saskatchewan. Aerial assessment of the final classification indicates good general agreement between the classification results and actual ground data for most cover types.

An estimated project time of 15-20 days, including fieldwork, would be necessary to complete a cover map on an operational basis. Photo interpretation of the same area would require approximately 150 days. The cost of the image data required to perform the classification is presently $850.00 compared to $30,000.00 required to cover the same area with air photos at a suitable scale. In addition to the obvious savings in man power and aerial coverage, serious problems may occur in obtaining acceptable recent air photo coverage for large areas due to weather constraints.

Additional savings in cartography can be expected with the completion of the classified map using an ink jet plotter for limited additions rather than standard colour printing techniques. Completion of this project included a full colour classified map "camera ready" for mass duplication.

Cover types of interest to wildlife biologists in northern Saskatchewan are very similar to those foresters concerned with forest fuels fire mapping. This suggests that northern mapping could involve inter departmental cooperation with joint funding ventures which could significantly reduce individual agency mapping costs.

Accuracy assessment on a pixel by pixel basis is difficult and requires the location of very specific sites on the ground. Accuracy assessment which compares the satellite generated thematic map with existing cover maps (ie. FIM) are limited by the errors built into the existing cover mapping.

The majority of disagreements between the FIM and the thematic maps were the result of differences inherent in the two maps.

1) Species resolution of the FIM's allows for up to 25% of undefined commercial forest species. This resulted in considerable disagreement between the two maps. Areas classified as pure stands on the FIM often were classified as mixedwoods because some other species occurred in the stand. They occurred however at less than 25% and therefore were detectable by the satellite sensors but were not defined by the general category used in the FIM. Areas classified as mixedwoods outlined species occur in a larger block of the satellite produced thematic map where often considered pure stands in the FIM map as the area contained a dominant species and less than 2.5% of any other species.

2) The mapping resolution (minimum area mapped) of the two maps differed resulting in some loss of information on the FIM (4 pixels) compared to the thematic map (1-2 pixels).

If accuracy estimates are adjusted to take into account the differences between the digitally produced thematic map and the FIM much higher levels of accuracy are apparent and come closer to reflecting the true potential of the Landsat classification of the area (Table 5).

Further work with various enhancement procedures would result in some additional separation of closely related reflectance clusters (i.e. classes).

The use of multi-date image analysis shows a great deal of promise in expanding the capabilities of MSS data and should be pursued further.

Digital Analysis of two season (summer and fall) imagery would increase accuracy in separating the major forest classes particularly the mixedwood classes.

Table 5.
Final Classification Results.

	Correct	Error
Water bodies	95	5
Softwood Dominant	86	14
Hardwood Dominant	83	23
Deciduous Mixedwood	28	72
Treed and Open Bog	82	18
Mean (5 classes)	75	
Mean (4 classes)*	87	
Median Score (5 classes)	83	

Note: *excluding mixedwood

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